Electronic Version
Stylesheet Version v1.1.1

Description

BLADE SAIL

BACKGROUND OF INVENTION

[0001] Traditional sails are troubled by shortcomings throughout the range of wind conditions. In "underpowered" conditions (where the sailor desires more boat speed), the sail must grow unwieldy in its large size, particularly when efficiency is desired (where a high mast-to-boom ratio is used), or else the boat sails at too slow a speed. In "overpowered" conditions (wind velocity higher than preferred), there is a desire to reduce the effective sail area, yet most sail designs must choose among a cumbersome "reefing" process (where portions of the sail are re-bundled), a "haul" process (where the tension throughout sail material must be manually adjusted) or "sheeting out" (where the sail - still cumbersome in its large size - is swung downwind to a less efficient angle to reduce the heeling loads on the boat). Even in "ideal" wind conditions, the traditional sail is cumbersome (the mast height is usually much higher than the boat is wide or long) and inefficient

(flexible fabrics are usually tensioned in an attempt to approximate the most efficient shape of a rigid airfoil). In order to turn the boat (either "tacking" or "jibing") - where the boat must now receive its propulsive wind from the opposite side of the boat (from port to starboard, or the reverse) - the sail and boom must "swing around", traditionally over and through the passenger area of the sailboat and sometimes under power from the wind, which causes most of the onboard injuries to sailing crew. This "swinging" of the sail - although it covers a wide sweep of angles - traditionally also does not offer the option of a "reverse", where the boat can be propelled aft or decelerated, thus causing most of the minor boat-to-boat and boat-to-dock collisions as sailboats coast unstoppably (unlike motored boats, which can be feathered between forward and reverse thrust). Even in these best-case sailing conditions, where the fabric of a sail has approximated the shape of an airfoil, the final sail shape typically only has a "leading edge" (the most efficient portion of the sail) of the length of the mast - and thus compared to the more efficient shapes (such as an airfoil of the wing of an airplane - with a long "span-to-chord" ratio), the "ideal" sailing conditions of a boat sail are still aerodynamically

poor, and cumbersome in mast height. This long mast height - traditionally accepted as part of a sail boat, because of the inability to otherwise create the more-efficient "leading edge" - produces a safety hazard in lightening and around suspended power lines, as well as making travel beneath bridges difficult. The long mast length also produces the undesired effect of giving "leverage" to the wind, which produces a "heel" (a port or starboard roll) on the boat during sailing. The resulting "knockdown" hazard - where the boat is rolled until the mast and sail touch the water - is further aggravated by these long-mast, fabric sails which become wet and submerged and resist righting the boat. Some boats - in an attempt to fight this long mast's heeling force and "knockdown torque" - are even carrying lead ballast in the keel of the boat (a vehicle where weight is particularly punitive).

[0002] This invention overcomes each of these shortcomings of the traditional sail.

SUMMARY OF INVENTION

[0003] This invention incorporates the common aerodynamic relationship of "multiple, high-aspect foils are more efficient than a single, broad foil" into a compact and flexible design of a propulsion system that is fitted for use on tra-

ditional sailing vessels (boats, sailboards, etc.), and featured to deal with the shortcomings of the current, traditional sails used on boats. The 'Blade Sail' is a collection of vertical airfoils, controlled by a central "pitch-feathering" connection, and acts as the most-efficient possible primary thrust device for bodies desiring aerodynamic propulsion. Optionally, a boom-mounted 'comb' of vertical airfoils can pivot around a 'mast' centerline, and rack-and-pinion-type control can adjust the pitch of each individual airfoil relative to the boom. In this manner, the individual blades can always be angled to provide the operator with the optimum aerodynamic effect, and the optional boom's 'comb' assembly can be rotated to access the wind in the desired angle. The Blade Sail incorporates the benefits of greater leading edge lengths and aspect ratios into a modern sail configuration, made possible by modern knowledge of airfoil aerodynamics, modern manufacturing technologies, and modern materials that will make the net assembly and use of the multiple (small) blades more practical than the current assembly of the larger, less-rigid, broad-chord, traditional sail assemblies.

Brief Description of Drawings

[0004] FIGURE 1: DEPICTION OF A RELATED CONCEPT OF MAXI-

MUM LIFT AND MINIMUM DRAG PER WETTED AREA FOR THE LEADING EDGE REGIONS OF TYPICAL BODIES IN SUB-SONIC AIRFLOW. This figure illustrates the common relationship of better performance at higher aspect ratios for the same sail area (brought about by the local concentration of pressure around the leading edge), how it is hampering the current performance of traditional sails (which have a significant area of the sail drawn over the boom), and how it is incorporated to the superior performance of this invention.

[0005] FIGURE 2: EXAMPLE OF MORE-EFFICIENT "BLADE SAIL" CONFIGURATION. This illustration shows an example of a Blade Sail in a "boomed" arrangement (an arrangement with a horizontal, pivoting, common member to the sail; a "boom"), along with an illustration of the boomed Blade Sail's use in different wind orientations.

[0006] FIGURE 3: EXAMPLE OF BOOMED vs. BOOMLESS BLADE SAIL ARRANGEMENT. This illustration shows a comparative example of a Blade Sail in a "boom-less" arrangement (an arrangement where the blades are distributed about the boat), along with an illustration of the boom-less Blade Sail's use in different wind orientations.

[0007] FIGURE 4: CONFIGURATION OF PREFERRED BLADE SAIL

MECHANISM. This illustration shows the preferred Blade Sail detail configuration, the function and control of the blade mechanism, and the resulting maneuver benefits of the Blade Sail.

[0008] FIGURE 5: EXAMPLE OF VARIATIONS IN BLADE SHAPES. This illustration shows examples of possible blade cross-sectional variations (compared to the preferred "double-edge" blade), including the "teardrop" and "airfoil" cross-sections, and indicating some expected performance changes for each.

[0009] FIGURE 6: EXAMPLES OF VARIATIONS IN BLADE POSITIONS. This illustration shows variations possible to the placement of the cross-section of the blades, as it relates to the pitch control loads and the resulting tendency of the boat toward "neutral thrust" (boat stops) when control is released from the Blade Sail (i.e. a man-overboard).

DETAILED DESCRIPTION

[0010] As illustrated in the artwork of FIG. 1 ("Depiction of a Related Concept of Maximum Lift and Minimum Drag Per Wetted Area for the Leading Edge Regions of Typical Bodies in Subsonic Airflow"), this invention incorporates the established aerodynamic relationship of "multiple, high-aspect foils are more efficient than a single, broad foil"

into a compact and flexible design of a propulsion system that is fitted for use on traditional sailing vessels (boats, sailboards, etc.), and featured to overcome the shortcomings of the current, traditional sails used on boats.

[0011] Some common proofs of this concept are turbines (where multiple narrow foils are used, rather than one long 'screw'), high-efficiency aircraft such as gliders and high-altitude craft (where the length-to-chord wing aspect ratio is raised to become more efficient), modern windmills (where multiple, narrow foils are used - to produce the most lift for the smallest amount of wind), and sailboard race fins (where the highest aspect ratio structurally possible is sought).

[0012] The 'Blade Sail' is a collection of vertical airfoils, controlled by a central "pitch-feathering" connection, and acts as the most-efficient possible primary thrust device for bodies desiring aerodynamic propulsion.

[0013] Optionally, as illustrated in FIG. 2 ("Example of More-Efficient 'Blade Sail' Configuration"), a boom-mounted 'comb' of vertical airfoils can pivot around a "mast" centerline, and rack-and-pinion-type control can adjust the pitch of each individual airfoil relative to the boom. In this manner, the individual blades can always be angled to

provide the operator with the optimum aerodynamic effect, and the optional boom's 'comb' assembly can be rotated to access the wind in the desired angle. The Blade Sail incorporates the benefits of greater leading edge lengths and aspect ratios into a modern sail configuration, made possible by modern knowledge of airfoil aerodynamics, modern manufacturing technologies, and modern materials that will make the net assembly and use of the multiple (small) blades more practical than the current assembly of the larger, less-rigid, broad-chord, traditional sail assemblies.

[0014] BEST MODE FOR CARRYING OUT THE INVENTION

[0015] The whole host of common sailing materials and manufacturing methods are appropriate for the assembly of a "Blade Sail", such as stainless steel cables, plates, pulleys, bearings, blocks, nylon lines, carbon fiber beams, fiberglass decks, aluminum posts - made rigid by, and providing rigidity from - tensioned wire, etc. There are no unique requirements of manufacture that are not already in use today by the sailing industry, and that would not be apparent by the included artwork of the invention. And, just as the traditional sails (and masts, and boats) for many years have benefited from a progression of increas-

ing sailor skill, minute mechanical and aerodynamic alterations, and material upgrades, this Blade Sail can similarly benefit from decades of minute refinement (although - this time - the refinements will be focused on the aerodynamically-ideal shape of the Blade Sail, rather than on a fabric triangle). However, some suggestions for manifesting the invention are described here.

[0016] Referring now more particularly to FIG. 3 ("Example of a Boomed vs. Boom-less Blade Sail Arrangement") and more particularly to FIG. 4 ("Configuration of a Preferred Blade Sail Mechanism"), it is anticipated that the multiple blades - whether mounted on a boom, or mounted into the deck of the boat - each have a "pinion" (a stainless steel gear or cam) at the bottom end of the blade. Just above this pinion (to protect it from the water and ambient hardware) is a seal and bearing (likely flush to 4 inches above the top of the deck of the boat or boom). Just below this pinion (approximately 6 inches below, for the scale of a typical 30 foot sailboat), is another bearing (unsealed, to allow access and drainage). By these two bearings - one on each side of the pinion, and both at the base of each blade - the axle of each blade is secured, and any aerodynamic thrust load is carried and passed into the boat (as is done

by traditional sails), while any pinion loads are balanced between the bearings and thus produce little bending moment on the blade shaft (which is - again, to scale for a 30 foot sailboat - approximately 1 inch in diameter, and up to approximately 10 feet long). During aerodynamic loading, the blades (in cantilever, vertically from the deck) can flex only moderately as they each are small, aerodynamic surfaces that distribute the propulsive load among them, and over a shorter lever arm than a traditional mast. Optionally - if desired - the tips of each blade can be secured (as traditional mast tips are secured) by anchoring with tensioned wire to the surrounding structure of the boat. Again - in each case of securing the base or tip of the blade shaft, or the base of the boom's vertical mounting post, or other - the same methods currently used on traditional masts and boat decks can be used to mount the Blade Sail - only with a greater confidence in safety factor as the same net Blade Sail load is (a) more distributed than from a "single mast/sail" and (b) at less of a bending-moment advantage (as the blades are shorter than a traditional mast).

[0017] The building of the Blade Sail on a boom is essentially identical to the building of a "boom-less" Blade Sail, ex-

cept that the blades are mounted into a horizontal beam (a "boom"), rather than into the deck of the boat. This horizontal beam can then be centered to make a "T" on a vertical post from the deck (similar to a short "mast") that need be no higher than to reach a traditional boom. Optionally - for more strength - the post can spear the boom (forming a lower-case "t") and extend near the tops of the blades to offer some tensioned-wire rigidity (as traditional masts are secured). The sailing of a boomed Blade Sail has a comparable need for control of the boom as with a traditional sail, except the Blade Sail boom has no bias to "swing downwind" (as it can be well-centered on the "mast", and thus can have a balanced amount of wind force on both sides of the mast). The boom can be controlled with the same type of lines, blocks, cleats, tracks, etc., as on a traditional sail, and the helmsman need only set the boom yaw angle for the major points of sail, and then trim the pitch of the blades thereafter.

[0018] The method for retrofitting an existing sailboat with a Blade Sail is possible, and direct, but may not provide all of the advantages of a compact, custom Blade Sail. Blades can be strung along a cable at fixed intervals at the top of each blade, then along a second cable at the bottom of

each blade. The top cable is run from the top of the mast to the tip (the "clew") of the existing, traditional boom (hanging the blades beneath the diagonal cable, like ice sickles). Then the bottom cable is run from the boom's clew to the boom's connection at the mast, tensioning the blades vertically between the top and the bottom cable. Then, the boat is ready to sail normally, except for the pitch adjustment of the blades. The boom would still be operated normally, except the helmsman would likely be able to keep the boom constantly "sheeted in", and do the finer pitch controls by the Blade Sail. The corners of each blade is joined to its neighbors by a tether (much like a window's horizontal blind blade angles are joined together), so that the helmsman can control the pitch of all blades by pulling one line (the "rack") along the bottom of the blades.

[0019] Referring again to FIG. 4 ("Configuration of the Preferred Blade Sail Mechanism"), with particular variations in mind as illustrated in FIG. 5 ("Example of Variations in Blade Shapes"), and FIG. 6 ("Examples of Variations in Blade Positions"), the method of operating the Blade Sail is similar in action - and identical in principle - to sailing with a traditional sail. The helmsman eyes each blade with the

mindset of bringing it to the optimum "angle of attack" (the angle between the apparent wind airflow direction and the chord axis of the blade), just as a helmsman normally "sheets in" or "sheets out" the boom on a traditional, triangular sail. In the case of the Blade Sail, the angle of attack adjustment (or "pitch" adjustment) is done by adjusting either the lever which drives the "rack" (in the "boomed" configuration, where each blade rests on a rack-and-pinion) or the line (which is run through the cams on each of the blades distributed throughout the "boom-less" configuration). On a typical reach, when the helmsman has "stalled" the sail (a high-drag, low-thrust condition - on both the traditional triangle and the Blade Sail), it is because the sail has been "sheeted in" too much (approaching 90 degrees to the wind) and it is time to release some of the line (or lever). When the helmsman's sail is "de-powered" (neither drag nor lift, in a windy condition), it is because the helmsman has released the line (or lever) to let the sail (or blade) "flag" parallel (0 degrees) to the wind. Lying between these two angles (0 and 90 degrees) is the optimum angle for maximum forward thrust - without overloading the boat with too much "heeling" force (the vector of lift and drag which is wasted - per-

pendicular to the keel and the forward thrust - and prying the boat over its own keel). In this region is where the Blade Sail may be most noticed as advantageous - where there is more thrust, less wasted force, and less leverage to the wasted force to tip the boat over (as the "centers of pressure" of the blades can be lower than the "center of pressure" of the large, traditional sail). Further, in the mentioned case of the "flagging" sail (or blade) - where the helmsman desires no forward thrust on the boat, the Blade Sail can also be "over-rotated" (to beyond 0 degrees to the wind), providing "negative thrust" if the helmsman desires a reverse or decelerating thrust - for example - pushing the blades to a -10, -15, -20 degree angle of attack, and so on. It should be noted, as described in FIG. 6 ("Examples of Variations in Blade Positions"), that the magnitude and the direction of "rack" force (pitch-control force) can be controlled by the designed placement of the foils on the pinion axle. In the case of a centroid-balanced foil, as depicted in FIG. 4 ("Configuration of the Preferred Blade Sail Mechanism"), the aerodynamic rack preference can be to "close" the blades. If it is desired to reverse this tendency, a spring can be optionally built in to "self-center" the blades at any desired pitch angle.

[0020] In the performance-oriented case of attempting to sail "close hauled" - as nearly into the wind as possible - the Blade Sail should exhibit its most superior characteristic of a high lift-to-drag ratio. For maximum fine-tuning, the mounting of the blades on a boom (described as the "boomed" Blade Sail) not only allows the pitch of the blades be adjusted for ideal angle of attack, but also the boom can be pivoted in yaw on the deck (much like the current boom of a traditional sail) to allow optimized presentation of these blades to the wind and aerodynamic interaction with one another. In this manner, the boom can be presented anywhere between 0 and 90 degrees to the apparent wind at all times, allowing the Blade Sail pitch to then be adjusted optimally to produce the lift needed for directional control of the boat.

[0021] In the particular case of sailing purely downwind ("running") - where no sail is particularly burdened for performance (as any object will drift downwind) - the Blade Sail still is compatible with traditional sailing methods. In the boomed Blade Sail case - the boom can be swung 90 degrees to the wind - across the beam of the boat, and all blades "closed" (stalled - to form a vertical wall). In the boom-less Blade Sail case - where the blades

are scattered around the deck of the boat - these blades can also be turned to stagnate the airflow and produce downwind thrust. If additional downwind performance is desired, a "spinnaker sail" (or "chute") can be deployed off the forward points of the boat - just like on traditional sailboats, when the normal "reaching" sail configurations are deemed unsatisfactory.

[0022] In storm conditions - where sailing has been forsaken and the minimum aerodynamic exposure is desired - the Blade Sails may exhibit safer characteristics. The near-rigid blades (vs. a tensioned fabric), short mast, and easily-tuned pitch, may allow control to remain further into the storm. But once the sailing has been abandoned, the Blade Sail pinions can be fully released to let each blade "flag" into its local apparent wind, thus reducing the aerodynamic drag to likely no more than a traditional empty ("dropped sail")mast and boom. In the case of a "knock-down", or pitch-pole, the shorter "masts" of the scattered, individual blades may produce less structural damage to the top deck of the boat than a large traditional mast. In the absolute worst-case storm conditions, the Blade Sails can be removed and stored below deck (or scuttled), to present the absolute bare-minimum, most durable, boat

profile for aerodynamics (high winds), hydrodynamics (boat rollovers and green-water waves), and lightening.

[0023]